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A NEW METHODOLOGY FOR THE MODELING OF DECISION PROCESSES IN INT--ETC(U)
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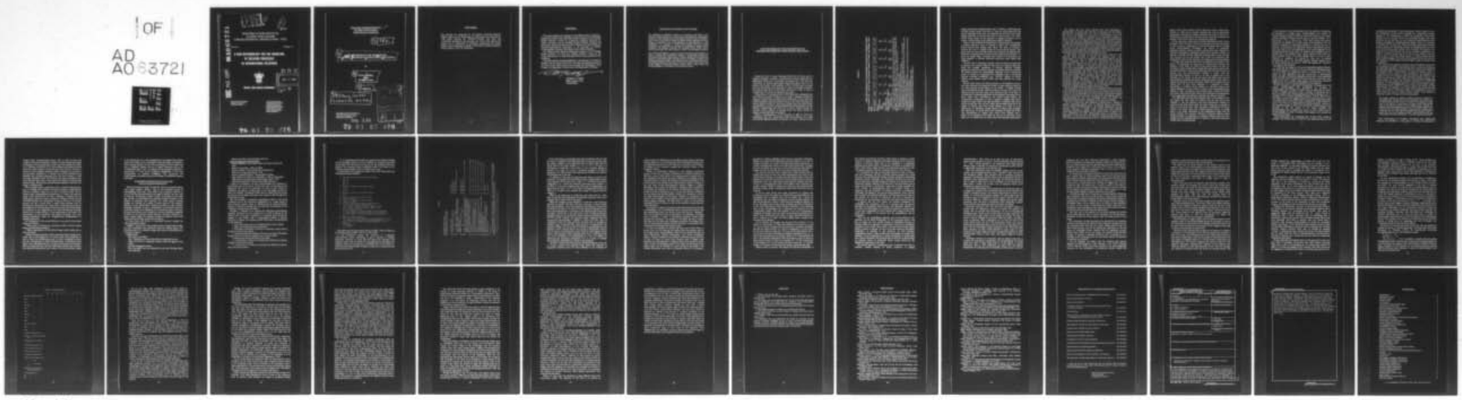

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A NEW METHODOLOGY FOR THE MODELING OF DECISION PROCESSES IN INTERNATIONAL RELATIONS

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A NEW METHODOLOGY FOR THE MODELING OF DECISION PROCESSES IN INTERNATIONAL RELATIONS.

by

(10) Warren R. Phillips
~~and~~
David McCormick

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FOREWORD

This memorandum was presented at the Military Policy Evaluation: Quantitative Applications workshop conference hosted by the Strategic Studies Institute in mid-1977. During the workshop, sponsored by DePaul University and the Strategic Studies Institute, academic and government experts presented the latest findings of formal models and statistical-mathematical approaches to the processes of military decisionmaking, assistance, intervention, and conflict resolution.

The Military Issues Research Memoranda program of the Strategic Studies Institute, US Army War College, provides a forum for the timely dissemination of analytical papers such as those presented at the workshop.

This memorandum is being published as a contribution to the field of national security research and study. The data and opinions presented are those of the author and in no way imply the indorsement of the College, the Department of the Army or the Department of Defense.

ROBERT G. YERKS
Major General, USA
Commandant

BIOGRAPHICAL SKETCHES OF THE AUTHORS

DR. WARREN R. PHILLIPS is Professor of Government and Politics at the University of Maryland where he teaches courses in the application of quantitative methods in policy planning and to international relations. He has just finished a major review of the quality of analysis in national security planning and is in the process of completing a book on the application of catastrophe theory to crisis management. As a manager of CACI's Policy Sciences Division, he gained experience in the application of quantitative methodologies to problems in the intelligence and planning community. He has headed several ARPA contract efforts and has spent two years as advisor to ARPA's crisis management program.

DR. DAVID McCORMICK is a senior associate of the Policy Sciences Division of CACI, a research firm specializing in analysis of international problems. Dr. McCormick has directed a large number of projects dealing with the quantitative analysis of international affairs. Included have been the design of models of less developed nations and studies of the Vietnam War, the Arab-Israeli confrontation, and political integration in Southeast Asia. Dr. McCormick has also been involved in the transfer of information theory, decision theory, control theory and artificial intelligence to the analysis of international problems.

A NEW METHODOLOGY FOR THE MODELING OF DECISION PROCESSES IN INTERNATIONAL RELATIONS

During the first 20 years following World War II, Soviet and US planners considered a military confrontation in Europe undesirable but significantly likely and so potentially catastrophic that it has been the cornerstone of military preparedness planning all along. From the US position the Soviets would mobilize in 30 to 120 days and we would know of this buildup in its third day of effort. Under these conditions the United States and its NATO allies would have at least 27 days to mobilize their own forces to respond to an attack.

Using this set of assumptions the NATO allies have configured their force structure in such a manner as to provide a maximum number of troops in a frontal line to prevent minor clashes and to be in a first line defensive position when the Soviets moved. It has been US policy that reserve divisions would be flown into Europe from the United States and elsewhere to provide a sustained defensive position against a Soviet military breakthrough and that US air power would provide the necessary reserve support by pinning down the enemy should he prepare more quickly than we estimate.

Recent reconsiderations of this scenario in light of both new information and new technology brings into question our whole conventional fighting position in Europe. As Table 1 points out, the

TABLE 1

Most Likely Scenario of a Soviet Buildup of Ground Forces along the Central Front, M Day to M + 120, by Type of Division, Number of Tanks, and Military Manpower

Force component	*M day*[a]	*M + 7*[b]	*M + 15*[c]	*M + 30*[c]	*M + 60*[c]	*M + 90*[c]	*M + 120*[c]
Divisions							
Motorized rifle	13	15	15	23	34	34	40
Tank	14	16	17	27	28	28	29
Airborne	...	...	5	5	5	5	5
Total	27[d]	31	37	55	67	67	74
Tanks[e] (thousands)	6.9	7.9	8.2	12.9	15.2	15.2	16.7
Military manpower (thousands)							
Total deployed[f]	339	401	453	677	842	842	937
Combat troops[g]	254	292	340	508	632	632	703

Sources: Authors' calculations, based on data in International Institute for Strategic Studies, *The Military Balance 1972–1973* (London: IISS, 1972), pp. 5–8; and T. N. Dupuy and Wendell Blanchard, *The Almanac of World Military Power*, 2d ed. (T. N. Depuy Associates, 1972), pp. 150–51.

a. Defined as the day on which mobilization begins.

b. All Soviet ground forces presently stationed in Eastern Europe.

c. For an explanation of the origin of additional forces appearing after M + 7, see Appendix B.

d. All Soviet divisions stationed in Eastern Europe with the exception of the four in Hungary, which are not considered opposite the Center until M + 7.

e. Includes only medium tanks assigned to divisions because they would probably be the only medium tanks fully manned and available for combat.

f. Deployed combat troops plus deployed support troops.

g. Represents 75 percent of total deployed military manpower.

Soviets could move instantaneously with 27 divisions, 7,000 tanks and 254,000 combat troops. In as few as 7 days, he could amass all of his Eastern European forces. Our own estimates are that if he were to seek limited objectives in the West and were to move in from 3 to 7 days, NATO forces would not be prepared to engage his advance and to sustain a viable defense until reserves were rushed to defense.

Since we take seriously the implications of this position, US planning is seeking numerous ways to respond to these new contingencies. Several actions have already been taken. The Army is moving to increase the ratio of combat troops to total troops in Europe. This means that the cook and bakers have been replaced with fighting men. Munitions are being moved to the front line troops in an attempt to cut down on supply times. Command and control (C^3) procedures are being designed to facilitate automatic redirection under highly fluid situations.

Now we come to a juncture, however. There are those who argue this is nowhere near enough. What we need now is to respond vigorously. Build new strategic capabilities to threaten (selective strategic retaliation) should the Soviets attempt any limited objective activities. We should increase the technological capacities of our conventional punch in Europe by employing force multiplier such as automated airborne command capabilities (e.g., AWAX). Further, we should develop cruise missiles, square bombs, and other effective but costly weapons.

Recent public debate has differed sharply on the likelihood of short lead time scenarios occurring in the future. A major question which has not been answered is how likely are the Soviets to actually attempt short mobilization limited objective actions in Europe. Of course, the minute we open this door many other questions arise. At the heart of the difficulty is understanding Soviet decisionmaking. We simply do not know under what circumstances the Soviets would believe the environment is opportune for such a gambit. Certainly they have a number of images which may take precedence at different times in the Soviet bureaucracy. But we don't really know enough about any of the images to specify what they would identify as a crisis or as an opportunity of significant enough import to initiate such strategies. One alternative, to equate intent with capability is simply too costly. The juxtaposition—to assume they would never attempt such a policy—is too dangerous. But where do we turn to determine a more likely set of scenarios and to derive from them planning implications?

We believe that the social sciences have been developing a methodology for dealing with this class of questions. We also believe that there is a pressing need to put such methodologies to acid tests such as the one implied in searching for an appropriate strategy to ensure the future of Europe without a nuclear war over mistaken ideas of what either side was willing and able to attempt. Previous attempts to apply decisionmaking models have failed for two reasons. Either the state of the art was such that we were admonished to consider much too much in a way too unstructured manner, Snyder (1962), or several routines restricted themselves unnecessarily by not taking advantage of the details of the decision process, Rappaport (1964).

In this article, we hope to show why the time is ripe for a new approach which promises to provide the discipline with a new methodology to be used for *modeling international behavior* and the policy community with a means for *discovering the principles underlying the decision process* in other countries. In short, we will argue that *it is necessary to develop models which will incorporate more of the contextuality impinging upon the decision processes* if we are to deal effectively with either basic or applied analysis of foreign policy decisionmaking. One of the means of doing this is the use of production systems. While inelegant, they provide the scientist with enormous investigatory power particularly when linked to extant numerical models. Furthermore, we will argue that models using production rules can be developed in a manner very similar to more traditional scientific analyses. They can be developed from a detailed structure, fit against data and finally tested against data.

We will present, in the introduction, the general trends in the study of international relations which have led to the need for research efforts of the sort we are proposing. The second section will present a general overview of production rules and the elicitation methodology useful in operationalizing the rule. The concluding section will outline the problems and approaches to validation of this form of modeling.

The last 10 years have seen significant funding from a number of research supporting agencies such as National Science Foundation, Advanced Research Projects Agency, the Defense Department, and the National Institutes of Health. These funds have been primarily supporting macro-level analysis of the characteristics of nations over time, identification of basic characteristic types of countries, and delineation of the patterns in the behavior of these nation types over time. Such approaches as those taken by R. J. Rummel (1965), J. David

Singer (1967), Bruce Russett (1967), Raymond Tanter (1966) and a number of others have certainly advanced the state of macro-level theorizing in international relations. Recently the work of North *et al.* (1968) made a strong case for the importance of periods of dynamics as applied to the forces of history in international relations.

At the same time, others such as Charles McClelland (1968), Chuck Hermann (1975), Ed Azar (1974) have attempted to look more closely at what could be characterized as micro-level phenomena of foreign policy decisionmaking. Throughout the history of empirically supported research, readers of various journals have been subjected to literature attempting to distinguish quality from quantity in these two schools of thought. Several important positions seem to have become well accepted in this last decade and a half of involvement with quantitative studies of the dynamics of foreign policy decisionmaking.

To begin with, statistics alone will rarely identify the structure of the theory for explaining the dynamics of foreign policy (Brewer and Brunner, 1975). Ando and Fisher (1963) have pointed out that it is necessary in linear models when dealing with input-output systems that the analyst break his model into subsystems and even then he must be assured that the intra-subsystem variance is greater than the inter-subsystem variance in order to be able to explain any of the dynamics of his system. In the end Ando and Fisher point out the inter-subsystem variance will finally destroy the ability of the model to explain the behavior of the total system. While this is certainly true at a formal level, we have been subjected to a multitude of studies attempting to correlate, factor analyze, or otherwise employ least square techniques on the actions of nations over increasingly shorter periods of time. According to the formal proofs of Ando and Fisher and others, these shorter time frames only accentuate the inadequacies of those approaches attempting to represent the relevant dynamics.

Two difficulties have become eminently clear in this research. First, the smaller the time frame the analyst uses, the less data he has available to test his structure. Thus more idiosyncratic behavior is captured in the data matrix when one moves from years to months to weeks to days in his time frame. Secondly, as Phillips (1973/75) has pointed out several times, the stimulus-response nature of foreign policy is not easily capturable in time aggregations larger than the actual stimulus and response. Therefore, statistical analyses which identify patterns or parameters for response behavior have also been trapped by the ecological fallacy as it applies to time frame analysis in foreign policy decisionmaking.

Early attempts to deal theoretically with the problem of identifying the dynamics of foreign policy decisionmaking rely heavily on stimulus-response models of either the simple SR variety or of the more complex mediated stimulus response (see for instance Phillips, 1973; McCormick, 1975, or North *et al.*, 1968). Such models have proven inadequate for dealing with foreign policy decisionmaking. There are numerous examples of quantitative attempts to replicate this sort of thinking. Unfortunately the difficulties become immediately obvious when one thinks about the implications of the model suggested by the underlying statistical work itself. For instance, how frequently have we thought about the likelihood that a given stimulus would result in a given response? Would the answer change even if we were to allow ourselves to reorganize the stimuli by some sort of internal interpretation such as the mediated stimulus response models? Don't we almost always ask the question "What else is going on?" before we try to guess at the response?

We find that the output of the system approaches random behavior even under the best of efforts to force structure into S-R explanations. It is not difficult for substantive experts to inform those of us who would try such approaches that the contextuality of international affairs can easily override any regularities which exist in such simplified models. Indeed, few of those who have even tried the quantitative work suggested by such a format make claims for tremendous theoretical sophistication or actual forecast capability in their approach.

Recent attempts to understand the dynamics of foreign policy and military decisionmaking have emphasized the necessity of understanding how decisions are made. Thus we argue that we need a model of thought processes in order to attempt to understand and to forecast foreign policy decisionmaking. Such diverse literature as V. V. Druzhinin *et al.*, *Concept Algorithm Decision: A Soviet View* (1972), and Allison (1969) have suggested there are multiple alternative models of thought which we need to be able to understand. Classic distinctions seem to boil down to a differentiation between empirical, rational, or S-R thought processes in which rules of behavior for given inputs can be provided so that the output of the system resembles real decisionmaking. But it appears that there is a more complex level of decisionmaking or model of thought which simply is not captured by these rational models.

What characterizes the "something else" of these other models of thought? The Soviets seem to think it is the dialectical nature of the

contradictions presented by the environment. Allison believes it is in the bureaucratic process itself including the competition between agencies in the bureaucracy to define the perspective under which decisions are to be made. We do not necessarily disagree with these positions but we feel they are only attempts at identifying when the image or paradigm for making decisions changes. They do not attempt to explain the fact that even when the standard operating procedures remain constant, the behavioral response to individual events as coded in the events data group is likely to be stochastic! The answers as to what the true forces involved are will be a complex combination of a number of factors we are sure. We are just as sure, however, that one must be able to determine which aspects of a given decision process make decisions appear as stochastic as they appear before one moves to the questions of which agency wins the right to apply its decision rules to a problem.

The reason for the apparent stochastic nature of behavior stems from the apparently cascaded or hierarchical nature of inference-making on the part of decisionmakers. Thus one does not recognize and respond to an individual piece of information, but rather he accepts a piece of information in the context of other information. This happens in a number of ways. For example, when one reads or codes *The New York Times* one does not see a story about the Soviets sending a threat to the United States, the reader also identifies information on USSR-CPR relations–or that information may have come from yesterday's paper. Interpretation of the USSR-USA story is made *in the context* of these other stories. The problem is, of course, which other stories and how long is the memory? Clearly the context for interpretation is not only other events but may be certain "lessons learned" from history or experience. Take for instance the following parable.

> For example, suppose you wanted to predict the success or failure of a large garden party. Assume that the party is less likely to be successful if it is crowded indoors because of rain. Your datum is the presence of a dark cloud on the horizon. The first stage of inference would relate the dark cloud to the presence or absence of rain during the party. Suppose you estimated that the probability of rain was .70. This estimate would become the input to the next stage of inference. If you knew with certainty that it would rain, then you could infer the probability that the party would be a success. But you are not entirely sure that it will rain; the data that you have indicates rain with a probability of .70, so how should you proceed?[1]

New developments in computer simulations have significantly enhanced the feasibility of using them to develop this approach to

foreign policy decisionmaking theory. But to date we have seen computer simulations developed to analyze theories dealing with images of long-term control perspectives of the outer environment (Forrester, 1971; Mesarovic and Pestel, 1974). These simulations identify problems which the world is likely to face in the next 20 to 50 years. The user or activator of the computer simulation mixes strategies in an attempt to solve problems identified in a "normal" run, and the simulation then identifies new problems generated from the user's attempt to solve previously identified issues. The difficulty with these simulations is the same difficulty with most of the macro-level analysis in international relations today. That is, little political decisionmaking is captured in the theory or analysis itself.

What is needed now is a simulation built to represent the process or style of dealing with problems (economic disasters, maldistribution questions, conflicts, crises, etc.) as they are believed dealt with by foreign policy decisionmaking bureaucracies. To answer the questions posed in the introduction, we need a capacity to identify how the USSR might respond to various contexts in Western Europe and the US-USSR relations. The end product of such an effort is a tool which analysts can use to learn about a given Soviet decision style by exercising the simulation with a wide variety of decision inputs and by observing the way in which these decisions are made. More importantly, *the approach we are suggesting is one which incorporates scientific discovery as a central element of the construction of the model.* The development of this simulation thus differs drastically from most existing simulations which are straightforward amalgamations of existing information.

The development of the model will have to account for three major classes of problems:

- What types of situations do particular models of Soviet foreign policy decisionmaking recognize?
- What interpretations do the Soviet foreign policy models give to these situations?
- What actions/productions would a particular Soviet foreign policy model take in this perspective? To answer these three questions, we need to study the underlying dynamic in Soviet recognition routines and the contextuality in which interpretations of individual events might occur. Although this type of model would imply more elements than is normally the case with the traditional numerical type of model, very important distinctions can be drawn. The most important change

is the introduction of a new mechanism for processing those factors which, both singly and in combination with each other, are thought to have dramatic impacts on the Soviet processing of direct stimuli. But such a capability requires the use of logical statements such as the combinatorial agent "and" as opposed to the summation principal so characteristic of most of the numerical aggregations of the past. Developments in artificial intelligence and production rule methodologies are suitable for just such tracings of conditional response theorizing.

OVERVIEW OF PRODUCTION RULES AND ELICITATION METHODOLOGY

What Are Production Rules? Production rules are statements which, when linked together, define a step by step sequential process of accomplishing some task. They differ from numerical methods by virtue of the fact that the latter do not claim to identify a process–only an outcome. Econometric models of GNP, for example, do not make any pretense of reproducing the individual decision processes of the millions of producers and consumers, but rather predict resulting changes as a function of a variety of metric inputs to the economy. Because of this characteristic, numerical models are quite efficient (although frequently wrong or inadequate). A production system (a production system is an integrated set of production rules) of the same process would describe more explicitly a process including recognition of inputs to the economy, initial reactions, secondary reactions, etc. Such a system might, for example, attempt to represent some of the decision criteria of major groups in the economy.

To help clarify the notion of production systems, consider the following simple examples.

Example l. Some of the most common forms of logic systems which are easily translatable into production rules are cooking recipes. The following recipe for cooking fried eggs could easily be transformed into a computer program.

Original recipe

Start with a cold skillet.

Add 1 Tablespoon of butter and melt over medium-low heat.

When the butter is completely melted, break the eggs into the skillet.

Add salt and pepper to taste.

Keep the skillet over the medium-low heat until the egg whites have solidified.

Remove the skillet from the flame and serve.

Natural Language Production Rules

Initial conditions–cold, empty skillet with burner turned off.

Start.

Butter not in skillet → Place in skillet

Butter in skillet → Turn on burner to medium-low

Butter not completely melted → Wait

Butter completely melted → Break eggs into skillet

Eggs broken into skillet but unseasoned → Add salt and pepper

Eggs seasoned, but egg whites still partially liquid → Wait

Egg whites solidified → Remove from skillet and serve.

In this set of statements, the user would examine the conditions on the left-hand side of the arrow. If they were true, the function on the right-hand side would be performed. If there is any conflict of conditions, precedence is always given to the rule higher on the list. Thus, for example, seasonings would never be added until the butter was placed in the skillet, the burner was turned on and the eggs were broken into the pan.

This first example is completely deterministic. That is, once initial conditions are set, the outcome is established. For a large variety of social systems, however, there is a definite need to create production systems in which an external user can interrupt the operation of the computer to interject his own inputs.

Example 2. Consider as an example the following extraordinarily simplistic interaction of two nations one of which is played by the external user. The other is played by a computer. Both nations are engaged in the familiar task of determining whether to allocate resources to military or economic growth. The rules of the interaction are the following:

1: There are twenty units to be divided between the two goals.

2: They can be allocated in any proportion.

3: The object of the game is to be able to allocate as many units as possible to the economic sector.

4: The government will collapse if there are more than five periods during which the economic strength is less or equal to three.

5: Nations may attack each other at any time.

6: A nation has a .6 chance of winning if the difference in military strength is one unit in its favor.

7: A nation has a .95 chance of winning if the difference is greater than one unit in its favor.

8: A conquering nation adds the economic and military strengths of the vanquished nation to its own. Initially, the computer nation will be provided with information by the user on the strength of the user's nation. If the computer nation is militarily weak, it can build up. If it becomes strong enough to win, it is likely to go to war.

The generation of a production system from these rules requires the following concepts (variables).

```
 D = the difference between the military strengths.
     d1 = -2
     d2 = -1
     d3 =  0
     d4 = +1
     d5 = +2
 E = economic strength of the computer nation.
     e1 = 1
     e2 = 2
     etc
 M = military strength of the computer nation.
     m1 = 1
     etc
ET = economic strength of the user's nation.
     same as code above
MT = military strength of the user's nation.
     same as code above
EC = economic categorization system (computer nation).
     ec1 = economic strength greater than four
     ec2 = economic strength less than or equal to three
     ec3 = economic strength less than or equal to four
 C = economic weakness counter
     co = no instances of economic strength less than three (0)
     c1 = one instance of economic strength less than three (1)
     c2 = two instances of economic strength less than three (2)
     etc
ED = economic weakness categorizer
     ed1 = fewer than three instances of economic weakness (C ≤ 3)
     ed2 = three or four instances of economic weakness (3 ≤ C ≤ 5)
     ed3 = five or more instances of economic weakness (C ≥ 5)
 B = behavior
     b1 = not attack
     b2 = attack
```

The following production system shown in Table 2 below is based on the following matrix [MM] = (D, EC, C, ED, B, M).

In this production system, the computer is a generally noncooperative player attempting to gain a position of military superiority sufficient to attack and win against the opponent. The computer nation will not permit the opposing nation to get ahead of it militarily under any circumstances. If stability were to be achieved, it would have the characteristics of slightly oscillatory movement near the poverty level ($E \approx 3$).

TABLE 2

set initial value of C to 0
set initial values of E and M to 10
receive values of ET, MT from user

1) let D equal to M-MT	1) D → M-MT
2) evaluate EC equal to 1 if E > 4	2) ec1 → EC, E > 4
3) " EC " " 2 " E ≤ 3	3) ec2 → EC, E ≤ 3
4) " EC " " 3 " E ≤ 4	4) ec3 → EC, E ≤ 4
5) if the economic strength is less than or equal to 3 then computer nation will increase its economic weakness counter by 1	5) (*, ec2, ***) → (**, C+1, **)[1]
6) evaluate ED equal to 1 when C < 3	6) ed1 → ED, C < 3
7) " ED " " 2 " 3 ≤ C < 5	7) ed2 → ED, 3 ≤ C < 5
8) " ED " " 3 " C ≥ 5	8) ed2 → ED, C ≥ 5
9) if nations are equal militarily and computer nation's economic position is greater than 4, then computer nation will increase its military spending[2] until military strength has been increased one unit	9) (d3, ec1, *, *, *, *) → (*, *, *, *, *, M+1)
10) if d3, ec3 and ed1(exist), then increase military strength by 1	10) (d3, ec3, *, ed1, *, *) → (*, *, *, *, *, M+1)
11) if d3, ec3 and ed2 then reduce military strength by 1 unit (stop military spending)	11) (d3, ec3, *, ed2, *, *) → (*, *, *, *, *, M-1)
12) if d4 and ec1, then increase military strength by 1 unit	12) (d4, ec1, *, *, *, *) → (*, *, *, *, *, M+1)
13) if d4 and ec3, then reduce military spending until strength is reduced by 1 unit	13) (d4, ec3, *, *, *, *) → (*, *, *, *, *, M-1)
14) if d2 then increase spending until military strength has been increased by 1 unit	14) (d2, *, *, *, *, *) → (*, *, *, *, *, M+1)
15) if d5, attack user nation	15) (d5, *, *, *, *, *) → (*, *, *, *, b2, *)
16) score economic strength of computer nation by twenty minus current military strength	16) E → 20-M
17) return to rule 1	17) return to 1

[1] The asterisk represents ignored information. For this particular production rule, if the economic strength is less than three; the economic weakness counter is incriminated by 1. All other information is irrelevant and there is no other immediate result of that economic status.

[2] Presumably by using some of its excess economic capability.

Notice that there are essentially three types of decision rules. For the first type, if conditions on the left-hand side of the arrow are met, then the actions implied on the right-hand side are taken. Such rules are found above in the steps number 5, 9, 10, 11, 12, 13, 14 and 15. If information is irrelevant to the action, it is not recorded. Instead an asterisk (*) is used. So in step 5 economic strength is all that is important. D, C, ED, B, and M are irrelevant and therefore not coded in the left-hand side of the rule.

In addition to this type of production rule, there is a need for the definition of categories and the setting of values. Categorizations are set by an equation of the form $ed(1) \rightarrow ED, C < 3$. Here the vector ED is categorized as a 1 under the conditions that some other variable C is less than 3. In its more complex form, this type of categorization can adopt the form $z(x) \rightarrow Z, Y = f(w)$. Here Z is categorized (x) when the value of Y is equal to the function f(w). Rules 2-4 and 6-8 fall into category 2.

There is one final form of production rule of the form $Z \rightarrow AxB$. Here Z takes the value defined by the arithmetic operation AxB. In our example, rules 1 and 16 are of this nature.

While the example is quite simplistic, it does serve some important illustrative purposes. The first, and most important, is that it shows how context plays a role in the production rule apparatus. Notice that d3 shows up in rules 9, 10, and 11 but the actions are dependent upon what other information is contained on the left-hand side of each rule. Secondly, it shows how a user can interact with a substantive decision algorithm based on the production system format by submitting values for ET and MT. Thirdly, the approach clearly delineates what the computer-as-a-decisionmaker considers as inputs and what types of complexity it has as a response mode. (One has only to compare the elements being considered with those ignored, as evidenced by the asterisks.) Finally, we can see that if one were to hypothesize that the behavior of the computer-nation was typical of the behavior of some class of nations, the production system could be tested against known history. This principle will be expanded upon, for it is the basis of the use of the production rule methodology as a tool, not simply for collecting and organizing information, but as a means of actually discovering the characteristics of Soviet decisionmaking.

The first of these illustrative purposes, the demonstration of the role of context, supports the argument made earlier that responses to apparently identical stimuli are often different. In our example, we

could consider the differences in the military power ratings as the basic stimuli. However, it can be easily seen that the behavioral response to any differences except a d2 or d5 will vary as a function of the context, as defined by the economic strength and economic history of the computer's nation.

Clearly, our substantive example is a very simplistic production system. If one were to attempt to improve it, it would be necessary to add more terms to both sides of the equations and to increase some of the complexity with which they were combined. For example, one of the improvements could be the addition of negotiating behaviors. This would require more variables to be entered into the system. Outputs, at the very least, would simultaneously include changes in military spending as well as offers (or refusals) to negotiate. Inputs would have to consider the existence of the process of negotiation as well as the results of previous negotiations, etc. It can be seen that the complexity of such systems can increase rapidly. Indeed, the complexity is one of the major disadvantages of the system. Certainly, in comparison with even the most complex of the numerical models, the production system format appears inelegant. We shall have to return to this problem eventually but first we need to take up the problem of generating the rules, themselves.

The success or failure of production rule endeavors depend critically on developing a set of behaviorally stable, substantively sensible rules and relationships which can interact in the way they are "supposed." The use of production rules is essentially a new language—or perhaps more accurately a means of structuring sentences (rules)—which describe the processes to be studied. To be useful, one has to believe that there are (a) stable, well established procedures for dealing with a class of international problems and that (b) there is a reasonably sound procedure for generating these decision rules.

To take an example, we believe that there are at least three—no doubt more—loci for defining and dealing with international crises in US foreign policy decisionmaking. These each are associated with the State Department, Defense Department, and Central Intelligence Agency. Cursory readings of any mumber of publicly popular accounts of how all three set about their business tend to suggest clear difficulties in operating rules.[2] It appears that the CIA prefers to define crises in terms of potential threats to the status quo sometime in the future which can be handled by covert actions in the present. The Defense Department sees crises as immediate threats to US property,

personnel, or military capability which must be responded to militarily. Finally, the classic State Department procedure appears to be that of viewing a situation as a threat to existing commitments, agreements, or treaties and diplomatic action as the only avenue appropriate. Certainly we have overstated the case but it is clear that there are quite different images at work here and that they have some considerable stability.

It is also the case that other countries have stable decision rules for dealing with crises and that they differ significantly from those in the United States. Bobrow, *et al.* argues that the Chinese define crises quite differently than the West and that the rules of behavior show a clear-cut difference in the way they handle crises (Bobrow, Kringen and Chan, 1976).[3] It is becoming quite clear that if analysts wish to forecast how another country is likely to respond to an issue, he must understand the decision strategy, image, or production rules under which that country operates!

It can be easily shown that Soviet procedures for dealing with problems do exist. The question is whether they are identifiable, in any meaningful way or whether they can be unified into a system or operational code. We believe the answers here are equally positive. We take the perspective of Simon (1969) when describing the behavior of an ant. He argues that it is the variety of signals and their combinations in the outer environment which exhibits complexity. The processing rules of *any* decisionmaker–ant or otherwise–are relatively few and comparatively simple. Thus the problem is not one of generating a multitude of decision rules, but rather of producing a parsimonious set which, when confronted with variety in input, generates responses in such a manner as to make the nation appear quite complex–even stochastic in its behavior.

Let us consider, for example, the reaction of R_y of nation "y" to a threat T_x from nation "x" given three elements of context c_1, c_2 and c_3. Let us assume, initially, that T_x and R_y are continuous functions and that for a given context "n," there is a mapping $R_y = f_n (T_x)$. Thus for the first context we have $R_y = f_1 (T_x)$, for the second there is $R_y = f_2 (T_x)$ and so on. But even under the simplest assumption (e.g., c_1, c_2, and c_3 can each hold only two values), there are $2^3 = 8$ permutations of the c's and therefore apparently 8 sets of functions $f_n (T_x)$. If there are three values of each c_n, there are a possible $3^3 = 27$ sets of functions. As the number of c's or the number of values which any "c" can take expand, the number of functions could become astronomically large.

Simon's point is, however, that despite the objective complexity of

the external environment (context within which a decision is made), there are a number of significant filtering mechanisms which reduce the number of functions which have to be considered to a manageable (perhaps quite small) number. Nonetheless, the failure to recognize that there is more than a single function can easily lead a researcher to infer a far greater stochastic element in behavior than is, in fact, the case.

To accomplish the task of generating production rules, we believe that most researchers will find a multiple research strategy more useful than the more unidirectional strategy normally employed in developing numerical models. Generally, the researchers will find that they will have to make use of multiple streams of evidence to fit the pieces of the simulation together. Because of the diversity of the information used as inputs and because a "production" system more closely resembles the "real" process of decisionmaking than do standard models, it is important that the researcher or research team have a considerable substantive knowledge of the process being simulated. (They will also have a need for the technical operation of production systems.) There is less latitude for the use of computers and data to provide the parameters for the simulation than is the case with numerical models.

It appears that the most useful and efficient mechanism for establishing the production rules is to proceed from the general principles to increasingly refined details. The alternative (which is to start from the development of a production system for a small number of cases and to generalize it) runs a serious risk of being so tied to the details from which it was formed that the generalization will be impossible.

There are two immediately apparent tools at the disposal of the developer for the *initial* development of the production system. The first is simply the very careful reading of established accounts of decisions taken as a response to certain events. Since we are specifically interested in the certain taxes under which the Soviets would initiate military actions in Europe, we would find their literature particularly applicable.[4] In addition to this literature, we have memoirs, congressional reports, public studies and chronologies to consult. This material is rich in perspectives on Soviet perceptions of opportunity from various viewpoints; the left-hand side of each rule. It also provides an extensive source on alternative Soviet actions which are the right-hand components of the rules.

The second approach to generating rules of behavior is to rely on thematic content analysis of public addresses of leading

decisionmakers.[5] Here there are at least two sets of information analysts would attempt to collect. The first elicitations should seek the "if . . . then" clauses existing in the statements. More finely grained analysis ought to identify co-occurrences of elements in either the left- or right-hand components of production rules.

Given the information from the detailed readings and the content analysis, the developers should be able to develop a basic structure for the simulation. Indeed, they should be able to complete operational segments of production systems which can be computerized and run to determine their implications. At this stage, the developers should be able to make at least some of the corrections for the obvious errors giving them a system (or at least a set of segments) which can be presented to experts in the area.

As a third methodology in the development of production rules, we anticipate the extensive use of substantive experts in the refining of the roughly formulated system. The experts will actually be used in three phases: (1) structured situational analysis; (2) open-ended review and elicitation; and, (3) refinement to fit the model to specific real world processes. While we would not suggest making these phases rigidly sequential, they will tend to follow each other. Hopefully, however, there would be some significant iteration between the phases.

Situational analysis is the first and most structured method of dealing with the substantive experts. To employ this method, the experts will be provided with information on a set of hypothetical unfolding events. These events would almost certainly arise from the exercise of the rough version of the production system. The flow of events would be stopped in midstream while the experts are asked a series of questions. What information do you feel you need at this point? What would you do if the information which you received looked like the following? What would you do if you were forced to act given only the information already presented to you? The form which these questions can take would naturally be quite varied. In some instances, the experts might be asked to estimate the behavior of other decisionmakers while in other cases, role playing might be a useful exercise.

Situational analyses are frequently used by analysts who wish to evaluate the information requirements for decisionmaking. We would argue that what is really being done is to ask experts to provide production rules so that technicians can ensure that the relevant information for selecting actions is available. Unfortunately, it is all too

frequently the case that irrelevant information is made available, thereby masking or swamping the necessary signals. We will show later how the formal production rule methodology can reduce (although not eliminate) this problem. We would expect that this use of the experts would generate additional production rules or alter some of those which had been previously developed.

The second use of the experts would be to review the production set and to permit them to observe decisions made by the computer given those segments already programmed. This stage will be the first serious look at the production system by Soviet area experts. It would take the form of both a critical review and a stimulus to suggest new or revised production rules. We believe that it would be useful in this phase to permit a number of iterations between observation of the rules, running of the program, reexamination of the rules, further revision, etc. until the total system begins to assume satisfactory face validity.

It should be noted that to this point, no formal analyses of data have been attempted. The work to this portion of the research would fall within what is normally considered the theory building phase. While we recognize that the effort contained in this extensive theory building is abnormally large, it is our opinion that it is really the only mechanism by which we can obtain a total production system which will be a sufficiently close isomorphism with reality to permit productive testing and further revision on selected case information.

The third use of the experts is in the actual testing and revision process using selected data on known situations. We will postpone a discussion of that use of the experts until the testing section of this paper.

The procedures we have discussed so far assume that the developer will have some general meta-theory which will govern the generation of the production rules from the very outset. Indeed without such, the rules would become very *ad hoc*, giving the appearance of bits and pieces of knowledge thrown together with no organizing concepts behind them. While we do not expect that anyone would seriously attempt to develop a simulation without such a meta-theory, it is probably worth mentioning that the meta-theory should be presented as explicitly as is possible.

For our purposes, we believe that the cognitive map concept described by Steinbrunner (1974), Bonham, *et al.* (1971), Bonham (1975), Axelrod (1976), and others provides a very useful organizing structure for the development of production systems. Indeed, the

production system should actually contain within it the equivalent of a cognitive map of the decision unit being simulated.

We argue that the initial element in the decision process is the cognitive map of the decisionmaker (or decisionmaking group). This serves as the interpreter through which all phenomena external to the decisionmaker(s) must pass. The cognitive map is the mechanism which weighs the importance of various elements of the context within which an event has occurred. It determines which aspects of a communication are most important and when to totally reject or alter a communication.

Over a few years time, the cognitive map will have a number of its elements altered. For example, the ways in which the United States views the Soviet Union and the Arab nations have shifted noticeably in the past few years. These represent changes in the cognitive maps because these basic images color the general context within which decisions are made, and they alter the meaning which US decisionmakers attach to the communications received from either the Soviet Union or the Arab nations.[6]

Similarly, there are also more basic changes in the cognitive maps of other decisionmaking groups. The Soviet's shift from Stalinist paranoia would be an example as would an apparent shift on the part of the United States from an attitude tending toward idealism of the 1940's and 50's to one closer to self-proclaimed "realism" of the late 60's and 70's. These changes in the cognitive maps are particularly significant because they serve to alter the mechanisms by which the decisionmakers process broad ranges of information.

This dynamism in images requires that the relevant elements of the cognitive maps of the decisionmaking groups be developed, as well as the mechanisms by which they can be changed. Substantive experts will be used to help provide the characteristics of the cognitive maps using the elicitation procedure discussed above.

Elements of the cognitive map are argued to be resistant to change as a function of (1) the length of time that the element has existed as a part of the map; (2) the frequency of its use; (3) the relative amount of information supporting it; and, (4) the number of other elements in the map which are logically linked to it. The first three of these factors are self-explanatory. The fourth recognizes that there is a desire to avoid cognitive dissonance resulting from elements of the cognitive map which are difficult to hold simultaneously. In the 1950's, for example, the official US attitude toward the world was strongly bipolar. This

attitude required the categorization of nations into either the "free world" or Communist bloc. Neutralism was not thought to be a legitimate alignment. As increasing numbers of nations indicated that they were, in fact, neutral in the US-USSR conflict, the two major powers had not only to recognize the reality of neutralism but to extinguish the bipolar beliefs and all of the associated images of the world.

The production system should be capable of altering its own cognitive map in accordance with the factors 1-4 above. The cognitive map, then, is the mechanism we would use to perform the initial translation of the outer environment into the left-hand side of the production rules. As we have argued previously, once that task is accomplished, the actual set of production rules which define behavior is rather simple. There are a number of decision algorithms which could be employed for the latter purpose. They range from traditional economic rationality to the satisfying principle (Simon, 1969) to nonpurposive adaptation (Ashby, 1960) to cybernetics (Steinbrunner, 1974). The choices between these (or their combinations) are really a function of the needs of the developers of their own production systems. Accordingly, we will not discuss that decision in this paper.

Dealing with Complexity. Thus far, we have introduced a belief in the necessity of micro-level modeling in international relations and a modeling tradition for structuring those models. This series of suggestions began with the belief that the "if . . . then" format of production rules is more consistent with the knowledge base of substantive experts than are the more numerical models which have been developed. This belief in myoptic rules over formal rules is consistent with business decisionmaking as viewed by economists (Nelson and Winter, 1972). Production rules demand a kind of detail and processed information (memory) rarely accumulated by statistical methods. Analytic solutions which may cut through the summing "morass" of assumptions *may* reproduce the output of a given decision unit but rarely show the style of decisionmaking or the processes so important if analysts are to understand the way others are coping with the international system.

Having presented the essential beauty of the approach we must now deal with its drawbacks. Production rules, like standard Operating Rules, have a way of accumulating all too quickly when analysts are asked to sit down and imagine all the necessary rules. Most procedures for aggregation of decision rules follow a topsy-like approach where the

addition or deletion of rules is rather *ad hoc*. These problems are compounded by the fact that it is difficult to find errant rules when one identifies abnormal behavior on the part of our computer decisionmaker. These problems are, of course, those of the whole class of complex models. Dealing with complexity is something one must approach with a good mix of caution and trepidation. Procedures are available which minimize their impact although they do not eliminate the problem.

The first simplifying procedure is the partitioning of conditions as was done in our previous example. Here we have, in effect, constrained the language of our decisionmaker to a very limited number of nouns and verbs. The most fruitful beginning in this area of limiting complexity is to limit the symbols that our decisionmaker is able to recognize. Not only can we limit the symbols but we can minimize the recognition and evaluation problems associated with allowing the user to use full English sentences by restricting the user to a checklist of values from, for example, -4 to +4 for each symbol. Such a procedure is outlined in Figure 1. Conditionals can now be written as combinations of values of this list. For instance, (*, B-3, *, *. . . Y-4) might be a pattern which would trigger a response. Response categorization can be equally formulated to make procedures simplified. Such exercises have two major advantages: (1) by structuring information about the environment and response behaviors they have greatly simplified the encoding problems associated with developing and evaluating the decision introduced and, (2) they have also made it possible to operationalize measures about the flow of behavior in the international system. Thus testing of the collection of production rules is facilitated because a coding form for organizing real world exchanges into comparable formats for the model is available.

Procedures for determining which production rules are apparently causing the system to respond improperly to external stimuli have been developed by Waterman (1970). By hierarchically structuring recognizable patterns as in the following example:

(*, B-3, *, . . ., *)

(A1, B-3, *, . . ., *)

(A1, B-3, C-2, . . ., *) it is possible to identify how the system distinguishes between contexts and to ascertain the appropriateness of such procedures. By keeping track of the number of patterns which are never recognized by the process, we can identify decision concerns (SOP's) which are either redundant or need to be placed higher in the hierarchy of decision rules.

Figure 1. Event Reporting

	-4	-3	-2	-1	0	1	2	3	+4
USR pol relations with X	-	-	-	-	-	-	-	-	-
CPR " " " "	-	-	-	-	-	-	-	-	-
USA " " " "	-	-	-	-	-	-	-	-	-
USR econ " " "	-	-	-	-	-	-	-	-	-
CPR " " " "	-	-	-	-	-	-	-	-	-
USA " " " "	-	-	-	-	-	-	-	-	-
USR mil " " "	-	-	-	-	-	-	-	-	-
CPR " " " "	-	-	-	-	-	-	-	-	-
USA " " " "	-	-	-	-	-	-	-	-	-
USA mil presence	-	-	-	-	-	-	-	-	-
USR " "	-	-	-	-	-	-	-	-	-
OPR " "	-	-	-	-	-	-	-	-	-
Domestic stability in X	-	-	-	-	-	-	-	-	-
Status of hostile US groups in X	-	-	-	-	-	-	-	-	-
Status of pro US groups in X	-	-	-	-	-	-	-	-	-
CP pro USR activity in X	-	-	-	-	-	-	-	-	-
CP pro CPR activity in X	-	-	-	-	-	-	-	-	-
Current unit cap of X	-	-	-	-	-	-	-	-	-
Current mil readiness X	-	-	-	-	-	-	-	-	-
Status of US citizens in X	-	-	-	-	-	-	-	-	-
" " " mil " "	-	-	-	-	-	-	-	-	-
" " " econ prop in X	-	-	-	-	-	-	-	-	-
Status of US diplomatic prop/personnel in X	-	-	-	-	-	-	-	-	-
Pol relations X-Y	-	-	-	-	-	-	-	-	-
Eon " "	-	-	-	-	-	-	-	-	-
Mil " "	-	-	-	-	-	-	-	-	-

We do not argue that complexity can be totally solved by systematizing procedures. We do believe that this manner of deliberate, phased building and exercising of a decision structure will minimize the loss of conceptual clarity. Much like the case study approach, this delineation of production rules requires the development of a detailed basic structure of the system to be modeled. This structure must be developed from substantive knowledge of the process to be modeled. It will provide the boundaries within which the experts will be permitted to express their knowledge through any of the procedures described above. Their role is largely to supply information, directly or indirectly, explaining which combinations of symbols are recognized and when (under what circumstances) actions are to be orchestrated. It should be emphasized that, for practical reasons, the experts should have only a minor role in the *development* of the structure.

Since the structure is of such central importance, it must be constructed with considerable care. Normally, it will reflect general characteristics of some class of actions for some broad class of actors. As such, its elements can be expected to come predominantly from existing writings. The goal of the developer should be to construct a structure which will be so specific that the validation exercises will be readily apparent.

Once the structure is developed, the research team must begin a data collection effort. The first step in this is to examine the structure to determine what information would be ideally wanted and which of that is likely to be accessible. For complex models, it must be anticipated that there will be many segments for which direct observations are not likely to be available. For example, if the structure were to deal in depth with the perceptual process, it is unlikely that there would be a detailed record useful enough to make explicit comparisons against the outputs of the simulation. Where such data are not likely to be available, the developers of the simulation should make an effort to collect information which will permit well-founded inferences.

Once the list of information needs is obtained, the developer must begin gathering extensive sets of narrative information describing chronologies of observed and interpreted events to which the eventual substantive model might reasonably be applied. Thus for example, if the current Persian Gulf interactions were being studied, the activities of the actors in that region for the past 20 years might reasonably be collected. Initially, these chronologies need be collected only in narrative form. Formal coding is not necessary at the early stages of the analysis.

Finally, the structure should be divided into logically identifiable units. Most complex simulations will probably be organized into hierarchies in which information is initially processed, the results of the processing being passed on to a lower level of the hierarchy. This hierarchical content is normally required to keep the system from searching its entire set of productions every time it receives an external stimulation.

The production rules will ordinarily be generated sequentially from the top of the hierarchy to the lowest. At each class, the developer must first select the concepts which will be the starting point of the class. This will be a large and critical stage for the top of the hierarchy, for it will receive the direct inputs from the user. The class of conditionals which start the process will be one of the primary strengths or weaknesses of any of these types of simulations. These will have to fit the format of the paradigm, but can take as broad a substantive range as the experts wish to supply. Here there will be constant questions of categorization schemes. The developer will be torn by the desire to have an elegant, parsimonious, general simulation, but one which also contains extensive detail. There will, however, have to be some categorization scheme, since it is not likely that the developer would want to list all possible concepts.

Once the input conditions are assembled and properly categorized, the production rules for that class must be created. Here again, the developer will have to interact extensively with all three classes of information to develop categories of inputs and categories of production rules. This is necessary to prevent a tendency to develop a production rule which predicts a single specific output if invoked by a specific permutation of conditionals. Instead, each production rule should be general enough to permit the processing of any of a *set* of concepts. This is difficult, but necessary if the simulation is to be applicable to a diverse set of problems (Feigenbaum, 1964).

For *all* of the classes of production rules, the output will be a set of concepts. For all except the last class, these concepts will be the input to the subsequent class. Thus in working on the subsequent class, a close examination of the required input concepts will provide a partial test of the adequacy of the previous class to supply them. This will be one useful test of the segments of the production system.

While working through these production rules there are certain to be decisions to be made regarding the form of some of the production rules. In essence, these decisions are similar to decisions between

alternative hypotheses which collectively will define the model. While some will be rejected for obvious errors, others will be hesitatingly rejected only because some alternate rule seems slightly better. Those which are rejected under the latter circumstances should be kept readily available along with the *a priori* estimates of their effects for review after each round of checking against data.

Testing. Once a segment has been tentatively developed, it should be subjectively compared against a sequence of decisions taken from the chronologies. These can either be selected as a relatively short time series or as a set of samples drawn from the total data set. The latter is a particularly powerful approach if temporal independence of the simulated behavior is a reasonable assumption (which in most cases it is not). In the former case, the production rules for the segment would be exercised to give predictions under the conditions known to exist during the testing sample. Since, at the segment level, it will often be difficult to find data which are directly comparable to the computer predictions, the criteria for acceptability will often need to be relaxed. Thus, we may not be able to look for explicit confirmation or disconfirmation. Rather, we may have to be temporarily satisfied with predictions which are *consistent* with known historical observations. There will, however, be a more formal, explicit test after the model is totally developed.

As a result of comparing the computer predictions with the chronologies, areas of inconsistency will be noted and the analysis will have to examine the reasons that the errors occurred. Once the incorrect rules are located, they can be revised. This may require the use of experts if the error is particularly subtle. In some instances, production rules which had been hesitatingly rejected may serve as useful substitutes. When the segment has been revised, it should be rerun against the initial chronologies. If the inconsistencies are not resolved, the process is repeated. If the inconsistencies are satisfactorily resolved, a run should be made against a new sample of chronologies. If there are new inconsistencies which need to be resolved, the process is repeated again until the first run against an unused set of chronologies yields satisfactory results. Once this is achieved, the analyst will proceed to the next level of the hierarchy of production rules. These production rules will be filled out and iteratively tested until there is convergence to a set of rules which satisfactorily reproduces known reality. This process is continued segment by segment until the entire production system is completed.

The reader will notice that this method is quite analogous to the process of using statistical methods of filling in the detail of hypothesized numerical models (i.e., estimating the parameters). Here, however, instead of using least squares types of measurements to adjust the errors, the developer is using a combination of (1) subjective judgment as to the degree of consistency between data and the predictions of the model and, (2) logical abilities to adjust the elements of the model to improve the fit.

Finally, after all of the production rules for all of the segments have been developed and subjected to these preliminary tests, more complete and formal tests must be performed. Because data are likely to be very scarce by the time the model has reached this point of testing, additional tests of face validity ought to be performed first. Conceptually these are very simple. The developer simply exercises the model through as wide a variety of inputs and contextual parameters as he thinks the system should be capable of handling. Here substantive experts can be employed fruitfully both to evaluate the plausibility of the computer's decisions and to add production rules or correct those which are in error. While this is conceptually similar to the testing of the segments, the developer/experts have the additional power to run the system through an extended period of time to examine the long-term stability of those rules whose effects are not always felt immediately.

Once face validity is established, more formal empirical validity must be established. There are two tests which can be performed. Both require the formal coding of the chronologies and the computer model's output into some coding scheme. Coding of chronologies here is analogous to the procedures employed in the events data movement. The first test would compare the time series from the previously used chronologies with the outputs of the simulation. With the user generating the historically known inputs to the system, the computer will be judged on the basis of its responses to these stimuli. If the simulation is a simple one, and history does not become a part of the context within which the decision is made, the analyses need not be made on a time-series basis. Rather probability density functions for classes of decisions can be made and the simulated versus the "real" can be compared independent of time.[7]

Putting the Models to Use. At this point, one is given cause to face the obvious question "What do we really have here except a new way of formulating 'If X then Y' computer statements?" In fact, that is mostly

what production rules are. We would argue, however, that the convergence of the technological developments of the past 5 years have created an opportunity analogous to that which was created for statistical analysis when high speed computers became readily accessible to social scientists a short decade ago. In 1965, we had most of the statistical tools that we have today. In fact in all of the social sciences, statistical/quantitative analysis was well known although not as widespread as it is today. However, the development of the large computers and the peripheral software merged well with a scientific need resulting in a rapid growth in the use of computers and statistics in the social sciences.

We believe that a similar condition exists today. There is a need for increased understanding of the systematic principles guiding international *processes.* The existing methodologies are partially inadequate. We believe that the major breakthroughs in this area are likely to come from *process* models of the form characterized by production rules. *Fortunately, most of the technical capability to do this exists to meet the need.*

The development of list processing languages, for example, make complex sets of production rules practical alternatives to numerical processing. (Those among you who know FORTRAN or PL-1 will know how time-consuming even simple logical programs (such as our examples) would be in those languages.) The work of Waterman (1970) has shown us how to interact with production systems during their development to improve them while they are being created. As a byproduct of these developments, we are currently witnessing a dramatic explosion of computer games on most university computers. Games ranging from Star-Trek, to checkers to chess to nearly all of the major card games (poker, hearts, etc.) can now be found on most university computers.[8] While a majority of these games are poorly programmed (easy to beat), there are a few on most systems which are virtually unbeatable. We mention this proliferation of computer games because it reflects the fact that the technology has developed to the point where many are developed in a production rule-type format. We suggest that this capability be expanded into a scientific tool useful for modeling international politics and, more importantly, for reaching a new plateau of scientific discovery which appears inaccessible with numerical models alone.

Notice, at once, that the simulation is quite different than most macro-level models. The objective of the latter is to predict an

environment in which we must make decisions. Do we like that future? Should we do something now to change it? How effective will we be in succeeding were we to wait 20 years? But a production system *is* the decisionmaker. Now we, the users, provide the environment and watch how our computer creature recognizes and solves the problems in our supplied environment. There are a number of questions that we can deal with here of some considerable importance when one is dealing with foreign policy decisions. Assume we have built a Soviet decisionmaker. Now our exercises ought to help us to understand better how the Soviets would define situations and how they would be expected to respond. Such activity is currently underway for the Chinese (Bobrow, *et al.*, 1976) and for Saudi Arabian decision styles (Thorson, 1976). Such models allow us to look at the implications for dealing with countries in one strategy or another. Questions about the context in which new initiatives are most likely to be successful ought to be answered with valid models. Disagreements between experts on estimates can frequently be decomposed to differences in assumptions about production rules or their order in the hierarchy. Once disagreements are identified, exercises against historical data ought to provide information on the relative merits of each position.

ENDNOTES

1. Gettys, *et al.*, pp. 364, 365.

2. See for instance *The Pentagon Papers,* Marchetti and Marks (1976) or Kennen (1967).

3. The Soviet case is most interesting here. Leites (1972) argues persuasively that the politbureau does indeed have an operational code. George (1971) recommends that we return to this problem as a research question.

4. In this vein there is a five set of translated material produced by the United States Air Force.

5. Here Admiral Gorshkov's statements are probably quite helpful.

6. See Holsti (1968) for an early attempt at finding John Foster Dulles' cognitive map or image.

7. Goodness of fit tests for both procedures are provided in Theil (1961) and Naylor (1971).

8. Frequently, these are programmed and loaded on computers covertly because of policies forbidding the use of such "wasteful noneducational" programs. University of Maryland officials, for example, are constantly engaged in a cat and mouse game with the students to locate these programs and purge them from the files only to find them somewhere else a few days later.

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In this memorandum, the purpose of the authors is to show why the time is ripe for a new approach which promises to provide the discipline of international relations with a new methodology to be used for modeling international behavior and the policy community with a means for discovering the principles underlying the decision process in other countries. They argue that it is necessary to develop models which will incorporate more of the contextuality impinging upon the decision process if we are to deal effectively with either basic or applied

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analysis of foreign policy decision making. One of the means of doing this is the use of production systems. The authors assert that they provide the scientist with enormous investigatory power particularly when linked with extant numerical models. Furthermore, the authors argue that models using production rules can be developed in a manner very similar to more traditional scientific analyses. They can be developed from a detailed structure, fit against data and finally tested against data. The authors present, in the introduction, the general trends in the study of international relations which have led to the need for research efforts of the sort they are proposing. The second section presents a general overview of production rules and the elicitation methodology useful in operationalizing the rule. The concluding section outlines the problems and approaches to validation of this form of modeling.

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